THE SCIENCE BEHIND THE THREAT OF GLOBAL WARMING/CLIMATE CHANGE

A Resource of the Unitarian Universalist Ministry for Earth, PO Box 11, Lyme, NH 03768
http://www.uuministryforearth.org

June 21, 2006 - Last edited July 26, 2006

This document describes the science behind the **Threat of Global Warming/Climate Change Statement of Conscience** (http://www.uua.org/csw/SOCFinal06_GW.pdf) adopted by the Unitarian Universalist Association of Congregations at their General Assembly meeting in St. Louis in June 2006.

The Presidents of the National Academies of Science of the United States, of all of the G8 countries, and of the three largest developing countries (Brazil, China and India), issued this joint statement in June 2005: *"There is now strong evidence that significant global warming is occurring. The evidence comes from direct measurements of rising surface air temperatures and subsurface ocean temperatures and from phenomena such as increases in average global sea levels, retreating glaciers, and changes to many physical and biological systems. This warming has already led to changes in Earth's climate."* [1] This statement indicates the solid scientific consensus that now exists. The degree of consensus was indicated earlier by a paper, **The Scientific Consensus on Climate Change**, by Dr. Naomi Oreskes, a professor of the history of science at UC, San Diego, in which she analyzed ten years of articles on climate change in the scientific literature. Contrary to claims by some that there is a lot of scientific uncertainty, she found that there were <u>no</u> papers out of nearly 1000 in peer-reviewed journals that disagreed with the scientific consensus that Earth's climate is changing as a result of human activities that are increasing the atmospheric concentrations of greenhouse gases (GHGs), especially carbon dioxide (CO_2).[2]

Earth's climate has varied considerably over time. This variability is a response to climate forcing factors that include: variability in solar radiation intensity, changes in Earth's orbit, changes in land surface, volcanic activity, and the concentrations of greenhouse gases (GHGs). Over most of Earth's history, such factors have been exclusively natural; however, particularly since the Industrial Revolution, human activities--primarily the burning of fossil fuels (coal, oil, and natural gas), and deforestation--have had an increasing influence on the global climate system. Since 1800 the atmospheric concentration of CO_2 has increased 30%, and average surface air temperature has risen approximately 1.4° F as a result of the enhanced greenhouse effect of this and other GHGs (water vapor, methane, nitrous oxide, troposphere ozone and CFCs (chlorofluorocarbons)). The concentration of CO_2 is now greater than at any time in the last 740,000 years and may reach a level not seen for 55 million years. [3]

Once emitted, CO_2 remains in the atmosphere for a long time. The mean lifetime of anthropogenic CO_2 is over 30,000 years.[4] (a) If all emissions from fossil fuels could be stopped immediately, the amount of CO_2 already in the atmosphere would result in continuing climate changes for hundreds of years. Earth's temperature was projected in 2001 to warm by from 2.5 to 10.4° F in this century unless major reductions in greenhouse gas emissions are made (60-80% below 1990 levels).[5] The upper limit of temperature rise this century has recently been revised upward by nearly 3-4° F because of the realization that the 2001 estimate underestimated the importance of feedback effects. (Warming causes increased GHG emissions from land and sea.)[6]

The idea that some gases in the atmosphere could make the Earth's surface temperature considerably warmer than it would otherwise be had been around for a long time. In 1859 John

Tyndall, an Irish physicist, built an apparatus (a ratio spectrophotometer) that allowed him to measure the fraction of light of different wavelengths transmitted or absorbed by various gases at different pressures.[7] He found that nitrogen and oxygen, which make up most of Earth's atmosphere, are transparent to both visible light and longer wavelength (infrared or IR) radiation, while others--like water vapor, CO_2 and methane, which we now call greenhouse gases—are also transparent in the visible but are partially absorbed and heated by infrared radiation, with more absorbtion as the concentration was increased. In order to have the Earth at a steady average temperature, the rate of absorbtion of incoming energy from solar radiation (insolation), which is mostly in the visible, must be equal to the rate of outgoing terrestrial radiation, which is mostly in the IR. He realized that Earth's surface temperature would increase if the concentrations of GHGs increased, but didn't attempt to make a quantitative estimate. That came from Svante Arrhenius, a Swedish chemist, who did many hours of tedious hand calculations during the year of 1894-1895 to estimate the effects on Earth's average temperature of halving or doubling the atmospheric concentration of CO_2.[8] While his model was primitive by modern standards, his estimate of a global average temperature increase of 9-11° F is not far from the current best estimates.

Water vapor is actually responsible for more than half of the greenhouse effect.[9] It behaves differently than the other trace GHGs, in that its atmospheric lifetime is only a few days, compared to much longer times for the others. Water is also unique in being present in all three phases (solid, liquid and gas) on the Earth's surface. The vapor pressure of water is strongly temperature dependent, leading to an important positive feedback known as the "water vapor feedback."[10] The importance of water vapor as a GHG can be seen in the large difference between day and nighttime temperatures in a desert, where the humidity is very low. As soon as the sun goes down the heat is rapidly radiated back into space.

The results of global warming are already being felt:

- 2005 had the highest global average temperature in the last 1000 years.[11]
- Antarctic ice shelves that have been in existence for at least 12,000 years as floating ice (and 125,000 years as ice grounded on the ocean floor) have disappeared completely[12]
- Mountain glaciers worldwide are in retreat, and the rates of melting are increasing; at least one quarter will be gone by mid-century.[13] Melting of these glaciers provides water for large numbers of people all over the world-- in the U.S. from the Rockies and Sierra Nevada, in South America from the Andes, and Asia from the Himalayas--300 million people in China alone.[14]
- Sea levels have risen about six inches during the past century; during the next, they may rise three feet or more, inundating large areas and resulting in unprecedented numbers of refugees.[15] An estimated 100-200 million people live within three feet of the present sea level. Bangladesh would lose 17% of its land, including half of its most productive rice-growing area.[16]
- Indigenous Arctic cultures, polar bears, and large marine mammals dependent on floating sea ice have been affected by the ~8% per decade decline in Arctic sea ice since 1979.[17] The summer of 2005 saw the smallest North Polar ice cap ever.[18] Arctic winter sea ice reached an all-time low in March 2006, down some 300,000 square kilometers compared to 2005. If the cycle continues, the Arctic Ocean could lose all of its ice by 2030, much earlier than expected.[19]
- The thickness of the North Polar cap, measured by U.S. nuclear submarines, has decreased by about 40% during the past 40 years.
- Warmer oceans and other human-caused stresses have already destroyed 20% of coral reefs; most reefs are at risk of dying by mid-century.[20]
- Increasing ocean acidity threatens coral reefs, mussels and scallops, and phytoplankton at the

base of the oceanic food chain.[21] Nearly half of the CO_2 released by burning fossil fuels dissolves in the oceans, forming carbonic acid, and making the water more acidic; enough CO_2 will eventually dissolve calcium carbonate, the major ingredient of coral skeletons and sea shells. Protein in the form of fish from the sea—a major protein source for millions of Earth's people--is likely to be severely reduced in coming decades by the growing acidification of the world's oceans.[22]

- Yields of major grain crops (corn, wheat and rice) are temperature sensitive. As temperatures increase, yields increase up to a point and then decline. A rule of thumb among crop ecologists is that a 1°C (1.8°F) temperature rise above the norm reduces grain yields by 10%. Global warming will make it increasingly difficult to feed Earth's growing population.[23]
- As temperatures increase, so do rates of evaporation and precipitation, leading to more severe droughts in some areas and floods in others.
- The area of Earth's surface experiencing serious drought has more than doubled since the 1970s, in accordance with the predictions of global climate models.[24]
- Insect and mammalian species across the northern hemisphere are migrating to cooler climates. [25]In the case of disease vectors like mosquitoes and ticks, this means spreading of diseases away from the Equator and to higher elevations.
- Globally, more people are victims of heat stress mortality, and the numbers of people exposed to vector-borne (e.g., malaria and dengue) and water-borne (e.g., cholera) diseases are rising. The World Health Organization estimates that at least 150,000 premature deaths each year are attributable to the effects of climate disruption (equivalent to a World Trade Center a week) and that the numbers will rise substantially over the next 25 years. [26] Climate change has many negative effects on human health, some of them quite surprising.[27]
- Tropical storm intensity and duration are linked to rising sea-surface temperatures. The destructive power of cyclonic storms has doubled over the past 30 years.[28] 2005 set new records for the most powerful hurricane (Wilma), the most destructive (Katrina), the most northeasterly (Vince), and the latest in a hurricane season (Zeta).
- Changes in climate are damaging habitats and disrupting ecosystems, and are expected to cause the loss of species that are unable to migrate or adapt. The first comprehensive assessment of extinction risk from global warming found that more than a million species—nearly a quarter of the plants and animals in the six ecosystems studied--could be extinct or on their way to extinction by 2050, if global warming is not curtailed. [29]
- Financial losses due to extreme weather events increased from about $4 billion/year in 1950 to about $40 billion/year by the year 2000, in inflation adjusted dollars.[30] Losses are expected to become much larger; they were well over $100 billion in 2005—twice what they were in 2004, which had record losses because of hurricane damage from four Florida hurricanes--because of Hurricane Katrina alone, which destroyed over 100,000 homes in New Orleans and the Gulf Coast. The increasing storm damage, disease, mass migration, starvation, and conflict, if we do not respond in time, will be beyond anything we have ever experienced.

Earth's climate system has sensitive thresholds, where sudden and extreme changes can occur, as shown by the paleoclimate record. Of great concern is the possibility that abrupt, irreversible climate changes with catastrophic consequences may occur once thresholds in temperature are reached. Examples are:

- The disruption of the Gulf Stream, resulting in sudden cooling of the climate of northern Europe and the Northeastern United States, even as Earth's average temperature continues to rise; [31] this happened coming out of the last ice age, in a period called The Younger Dryas, when northern Europe fell back into an ice age for more than 1000 years.[32]

- The rapid melting of the Greenland ice sheet, which is nearly two miles high in places. Total melting could raise the global sea level over 20 feet.[33] The combined melting of Greenland and the West Antarctic ice sheet could raise the sea levels by 43 feet.[34] Very recently it has been found the Greenland ice sheet is melting much faster than predicted; instead of the previously accepted 3 foot rise in sea level this century, there could be a 23 foot rise by 2100, leading to vast flooding of coastal areas throughout the world.
- A massive and self-perpetuating release of carbon dioxide and methane from thawing of peat bogs in Siberia, long frozen in permafrost, [35] and a self-perpetuating runaway temperature increase which could get out of our control.
- Fifty five million years ago there was an extinction event on land and sea called the Paleocene-Eocene Thermal Maximum (PETM),[36] attributed to the rapid release of 2000 Gt (a Gt or gigaton is a billion metric tons) of carbon in the form of methane. (For comparison, the atmosphere now contains about 720 Gt of carbon in the form of CO_2). Oxidation of the methane to CO_2 and its absorption by the ocean would make the ocean acidic enough to account for the disappearance of calcium carbonate from the ocean, as seen in the change in sediments on the sea floor. The methane probably came from the thermal decomposition of methane hydrate, which is present in vast quantities on the sea floor and can decompose to release methane gas if the temperature on the sea floor rises by 2-3° C (ca. 4-6° F).[37] Estimates of the amount of methane now frozen in hydrates range from 1000 to 22,000 Gt, with may experts putting the figure at about 10,000 Gt – 5X the amount released to account for the PETM! Burning enough fossil fuel to destabilize the methane hydrate could set the time bomb off. This is probably the greatest threat to the continuation of human life on the planet.

Proven technologies capable of stopping the increase in carbon emissions for the next 50 years, over which time they would otherwise double (based on current growth rates), are already available. Drs. Pacala and Socolow, at Princeton University, list 15 that are ready to go, including: more efficient vehicles, more energy-efficient buildings, nuclear power, CO2 capture and storage from coal-fired power plants, photovoltaic (pv) electricity, wind power, and biomass fuel.[38] Though none of these is capable of stabilizing emissions by itself (no magic bullet), a combination of them can.

The Pew Center on Global Climate Change has released a comprehensive plan to reduce greenhouse gas emissions in the United States. The ***Agenda for Climate Action*** identifies both broad and specific policies, and calls for a combination of technology and policy in six key areas: (1) science and technology, (2) market-based programs, (3) sectoral emissions, (4) energy production and use, (5) adaptation, and (6) international engagement. Within these six areas, the Agenda outlines fifteen specific recommendations that should be started now.[39]

REFERENCES

[1] **Joint Science Academies' Statement: Global Response to Climate Change.** http://www.nationalacademies.org/onpi/06072005.pdf

[2] Naomi Oreskes, **BEYOND THE IVORY TOWER: The Scientific Consensus on Climate Change,** ***Science***, Vol. 306, p.1686, (December 3, 2004). http://www.sciencemag.org/cgi/content/full/306/5702/1686

[3] Lester R. Brown, **Plan B 2.0 – Rescuing a Planet Under Stress and a Civilization in Trouble,** Earth Policy Institute, W.W. Norton & Company, NY, early 2006, p. 59.

---

[4] David Archer, **Fate of Fossil Fuel CO_2 in Geologic Time**, ***J. Geophys. Research***, Vol. 110, C09S05. http://geosci.uchicago.edu/~archer/reprints/archer.ms.fate_co2.pdf

[5] *Intergovernmental Panel on Climate Change (IPCC)*, **Third Assessment Report 2001**, Geneva, World Meteorological Organization. http://www.ipcc.ch/

Also Robert M White, **Climate Systems Engineering**, ***National Academy of Engineeringof the National Academies***, Vol. 31, Number 1, Spring 2001. http://www.nae.edu/nae/bridgecom.nsf/weblinks/KGRG-4X3J2V?OpenDocument

Also **Overview**, Our World Foundation: http://www.ourworldfoundation.org.uk/over-nof.htm

[6] Margaret S. Tom and John Harte, **Missing feedbacks, asymmetric uncertainties, and the underestimation of future warming.** ***Geophysical Research Letters, American Geophysical Union,***, Vol. 33, L10703, Published May 26, 2006. http://www.agu.org/pubs/crossref/2006/2005GL025540.shtml

[7] Elizabeth Kolbert, **Field Notes from a Catastrophe – Man Nature, and Climate Change**, Bloomsbury Publishing, NY, 2006, pp. 35-39.

[8] Elizabeth Kolbert, *op. cit.*, pp. 39-42.

[9] Peter Schultz in the Global Warming exhibit at the Marion Koshland Science Museum of the National Academy of Sciences, in Washington, DC. See: at www.koshlandscience.org.

[10] Elizabeth Kolbert, *op. cit*., p. 106.

[11] Dr. James Hanson, **GISS Surface Temperature Analysis**, **Global Temperature Trends: 2005 Summation**, ***NASA Goddard Institute for Space Studies***, December 15, 2005 with minor revisions January 12, 2006. http://data.giss.nasa.gov/gistemp/2005

[12] **Larsen B Ice Shelf Collapses in Antarctica**, ***National Snow and Ice Data Center***, Posted 18 March 2002. http://nsidc.org/iceshelves/larsenb2002/index.html

[13] **Glacier Mass Balance Data 2004**, ***University of Switzerland***, 12 December 2005 http://www.geo.unizh.ch/wgms/mbb/mb04/sum04.html

Also: **Global Warming Science, *Union of Concerned Scientists*, p**age last revised September 7, 2005, http://www.ucsusa.org/global_warming/science/

[14] **Connecting Arctic Sea Ice and Tibetan Plateau Snow Cover?,** ***Science Poles***, the scientific web site of the International Polar Foundation. http://www.sciencepoles.org/index.php?s=2&rs=home&uid=679&lg=en

[15] James G. Titus, **Greenhouse Effect, Sea Level Rise and Land Use**, ***Land Use Policy, Global Warming Publications, U. S. Environmental Protection Agency,*** April 1990, Vol. 7, Issue 2, pp. 138-53.

http://yosemite.epa.gov/oar/globalwarming.nsf/0/85256c870070ee7285256c3000568590?OpenDocument

[16] Lester R. Brown, **FACING THE CLIMATE CHALLENGE: The Rising Costs of Climate Change, *The Earth Policy Reader*, Earth Policy Institute, W.W. Norton & Co., NY, 2002.** http://www.earth-policy.org/Books/Epr/Epr1_ss14.htm

[17] **Satellites See a Double-Texas Sized Loss In Arctic Sea Ice, *NASA Watches Arctic Ice***, Sept. 28, 2005. http://www.nasa.gov/vision/earth/environment/arcticice_decline.html

[18]Jeffrey Kluger, **The Arctic Meltdown Speeds Up**, ***Time***, Sept. 29, 2005. http://massclimateaction.org/news%20articles/ArcticMeltdownSpeedsUp,TimeMag092905.htm

[19] David Adam, **Meltdown fear as Arctic ice cover falls to record winter low, *Guardian Unlimited***, May 15, 2006. http://www.guardian.co.uk/science/story/0,,1774815,00.html

[20] **Global Warming Puts Half of All Reefs at Risk, *Environmental News Service***, Oct. 25, 2005. http://www.ens-newswire.com/ens/oct2005/2005-10-25-05.asp

[21] Michael McCarthy, **Carbon Dioxide Turning Oceans Acid, Scientists Warn, *The New Zealand Herald***, April 2, 2005. http://www.nzherald.co.nz/section/story.cfm?c_id=5&objectid=10009477

Also: ***Pacific Marine Environmental Laboratory CO_2 Program,*** (part way down page) **Impacts of Ocean Acidification on Coral Reefs and Other Marine Calcifiers, *NOAA***, July 5, 2006. http://www.pmel.noaa.gov/co2 Full article: http://www.ucar.edu/communications/Final_acidification.pdf

[22] **Ocean Acidification Threatens Cold-Water Coral Ecosystems**, ***Biology News Net***, April 3, 2006. (Source: Ecological Society of America) http://www.biologynews.net/archives/2006/04/03/ocean_acidification_threatens_coldwater_coral_ecosystems.html

[23] Lester R. Brown, *op. cit*., p. 65.

[24] **Drought's Growing Reach: NCAR Study Points to Global Warming as Key Factor, *National Center for Atmospheric Research & the UCAR Office of Programs***, January 10, 2005. http://www.ucar.edu/news/releases/2005/drought_research.shtml

[25] **Global Warming Kicks Off Migration**, ***CBS News***, January 2, 2003. http://www.cbsnews.com/stories/2003/01/02/tech/main534993.shtml

[26] Jonathan A. Patz et al., **Impact of Regional Climate Change on Human Health, *Nature***, Vol. 438, pp. 310-317, November 17, 2005. http://www.nature.com/nature/journal/v438/n7066/abs/nature04188.html

[27] Paul R. Epstein, **Climate Change and Human Health, *New England Journal of Medicine***, Vol. 553, Oct. 6, 2005, pp. 1433-1436. www.med.harvard.edu/chge/course/atmospheric/health/health.htm

and direct to article, http://chge.med.harvard.edu/publications/journals/documents/nejm.pdf

[28] Kerry Emanuel, **Increasing Destructiveness of Tropical Cyclones Over the Past 30 Years**, ***Nature*** advance online publication; published online July 31, 2005. http://www.nature.com/nature/journal/vaop/ncurrent/abs/nature03906.html#a1

[29] Chris D. Thomas *et al.*, **Extinction Risk from Climate Change**, ***Nature*** Vol. **427**, pp. 145-148, January 8, 2004. http://www.nature.com/nature/journal/v427/n6970/abs/nature02121.html

[30] Koko Warner and Paul Freeman, **Vulnerability of Infrastructure to Climate Variability: Current Situation and Future Prospects**, July 25, 2001. http://www.iiasa.ac.at/Research/RMS/dpri2001/Papers/koko.pdf#search='financial%20losses%20from%20extreme%20weather%20events'

[31] Robert B. Gagosian, **Abrupt Climate Change: Should We Be Worried?, *Woods Hole Oceanographic Institution***, prepared for a panel on abrupt climate change at the World Economic Forum, Davos, Switzerland, January 27, 2003. http://www.whoi.edu/institutes/occi/currenttopics/climatechange_wef.html

[32] Thomas R. Karl and Kevin E. Trenberth, **Modern Global Climate Change**, ***Science***, Vol. 302, 5 December 2003. http://www.cleanair-coolplanet.org/information/pdf/Science_Modern_Global_Climate_Change.pdf

[33] Richard Z. Poore et al., **Sea Level and Climate**, ***US Geological Survey***, Fact Sheet 002-000, January 2000. http://pubs.usgs.gov/fs/fs2-00/

Also: Andrew C. Revkin, **More Greenland Ice Flowing Into Sea, in Sign of Warming, *The New York Times*,** February 16, 2006. See: http://www.nytimes.com/2006/02/16/science/16cnd-ice.html?_r=1&oref=slogin

Also: Michael Oppenheimer, **Ice Sheets and Sea Level Rise: Model Failure is the Key Issue, *Real Climate***, 26 June 2006, See: http://www.realclimate.org/index.php/archives/2006/06/ice-sheets-and-sea-level-rise-model-failure-is-the-key-issue/

Also: James Hanson, **The Threat to the Planet, *The New York Review of Books***, Volume 53, Number 12, July 13, 2006, http://www.nybooks.com/articles/19131

[34] Michael McCarthy, **Dramatic Change in West Antarctic Ice Could Produce 16ft. Rise in Sea Levels, *The Independent/UK*, February 2, 2005. See:** http://www.commondreams.org/cgi-bin/print.cgi?file=/headlines05/0202-04.htm

Also: Martin Siegert et al., **New Structure Found Deep Within West Antarctic Ice Sheet,** British Antarctic Survey, Press Release, September 23, 2004, No. 13/2004. http://www.antarctica.ac.uk/News_and_Information/Press_Releases/story.php?id=106

[35] Ian Sample, **Warming Hits 'Tipping Point'**, ***The Guardian***, August 11, 2005. http://www.guardian.co.uk/climatechange/story/0,12374,1546824,00.html

[36] James C. Zachos et al., **Rapid Acidification of the Ocean During the Paleocene-Eocene Thermal Maximum, *Science,*** Vol. 308, 10 June 2005, pp. 1611-1615. http://www.sciencemag.org/cgi/content/abstract/308/5728/1611

[37] Barbara Maynard, **Burning Questions about Gas Hydrates, *Chemistry,*** Winter 2006, pp. 27-33.

[38] S. Pacala and R. Socolow, **Stabilization Wedges: Solving the Climate Problem for the Next 50 Years with Current Technologies**, ***Science***, **305**, 13 August 2004. http://fire.pppl.gov/energy_socolow_081304.pdf

[39] **Agenda for Climate Action, *Pew Center for Global Climate Change***, February 2006 http://www.pewclimate.org/global-warming-in-depth/all_reports/agenda_for_climate_action/index.cfm

Contributors: Jackson Harper, Bruce Langmuir, Chad Tolman (primary author); members of the Unitarian Universalist Ministry for Earth, an affiliate of the Unitarian Universalist Association.

Last edited July 25, 2006